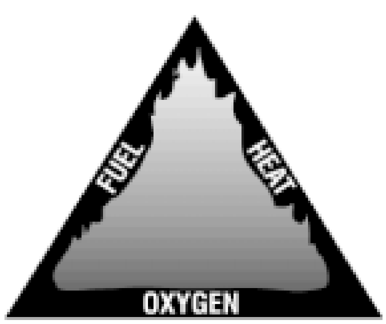
The Science of Wildland Fire

When communicating about wildland fire management issues, it is important to include the basic scientific tenets of wildland fire, including an examination of the combustion process and the factors influencing wildland fire behavior. Depending on the expertise of the audience, a communicator may choose to limit the discussion to a simple overview of the fire triangle, or expand the discussion to include the technical details of flame structure and fuel chemistry for those who need that level of explanation. This section is intended to provide the communicator with an overview of the scientific processes occurring with wildland fires. An excellent resource for a more detailed understanding of these concepts is *Introduction to Wildland Fire* (1996) by Stephen Pyne (et al.).

The Fire Triangle

The first step in teaching about wildland fire is to begin with the essentials as illustrated by the fire triangle and its three equal sides, representing heat, fuel, and oxygen; the interaction of the three are required for the creation and maintenance of any fire. When there is not enough heat generated to sustain the process, when the fuel is exhausted, removed, or isolated, or when the oxygen supply is limited, then a side of the triangle is broken and the fire is suppressed. The underlying theme is that wildland fire personnel seek to manage one or more of the three elements in order to suppress an unwanted fire or guide a prescribed fire.



Heat

Heat can refer to several aspects of wildland fire. A heat source is responsible for the initial ignition of wildland fires, and heat is also needed to maintain the fire and permit it to spread. In addition, heat is constantly emanating from the fire, warming the surrounding air and preheating fuel in its path.

Heat transfer is a critical issue in the study of wildland fire. For a fire to grow and spread, heat must be transferred to the initial and surrounding fuel. Heat allows fire to spread by removing (evaporating) the moisture from the nearby fuel, enabling it to travel more easily. The mechanism and the speed of heat transfer play a great role in wildland fire behavior.

Three mechanisms of heat transfer exist: convection, radiation, and conduction. All three contribute in different ways to the combustion process, depending in part on the available fuel distribution, the wind speed at the fire site, and the slope of the terrain.

Convection is the transfer of heat through the flow of liquids or gases, such as when hot air rises through a chimney. Convection currents are often responsible for the preheating of the higher shrub layers and canopy, carrying the groundfire upwards into the canopy.

Radiation transmits heat by rays, such as from the sun or a flame. Radiation accounts for most of the preheating of fuels surrounding a fire. The temperature of these fuels can sometimes grow so high that the fuels ignite prior to contact with flames, spreading the fire.

Conduction moves heat from one fuel particle to the next, as when the stove burner heats a pan and its contents. Conduction allows the heat to be transferred inside and throughout the fuel, rather than only heating the surface. Because wood is a poor heat conductor, meaning heat does not pass through it easily, conduction is usually not the primary mechanism of heat transfer in a wildland fire.

Fuel

The fuel side of the fire triangle refers to both the external and internal properties of the fuel. External properties refer to the type and the characteristics of the fuel material. Internal properties of fuel address aspects of fuel chemistry. Types of fuel include living vegetation, dead vegetation, (duff, twigs, needles, standing dead snags, leaves, and moss), organic subsurface material (peat and coal), and human built structures. Fuel can be defined as any combustible material.

Fuel is characterized by its moisture content, size and shape, quantity, and the arrangement in which it is spread over the landscape. The moisture content of any fuel will determine how easily that fuel will burn. Live trees usually contain a great deal of moisture while dead logs contain very little. Before a wet fuel can burn, the moisture must be converted to vapor through the heat process. The greater the moisture content, the higher the heat temperatures required to dry the fuel. The presence of moist fuel can affect the rate and direction that a wildland fire spreads. High moisture content slows the burning process since heat from the fire must first expel moisture.

The size and shape of fuel in part determines its moisture content. Lighter fuels such as grasses, leaves, and needles quickly expel moisture, and therefore burn rapidly. Heavier fuels, such as tree branches, logs, and trunks, take longer to warm and ignite. In areas of light fuel, the temperature required for ignition is lower than in areas of heavier fuel. The oxygen surrounds lighter fuels and allows the fuel to burn with greater intensity, quickly exhausting the fuel supply.

The quantity of combustible fuel in a given area is known as fuel loading. These fuels may be arranged in a uniform pattern and distributed continuously across the ground, allowing a wildland fire to travel uninterrupted. Or, the fuel may be distributed unevenly in a patchy network, forcing the fire to travel over rocks and other barriers by wind-borne embers.

The vertical arrangement of fuel is also an important factor in wildland fires. Ground fuels are all of the combustible materials found below the ground surface, and include tree roots, duff, and organic material. Surface fuels are found at the ground level, including twigs, grass, needles, wood, and other vegetation. Aerial fuels are standing vegetation including tree crowns, branches, leaves, snags, and hanging moss. Crown fires are able to burn independently of surface fires, moving through the treetops.

Oxygen

The third side of the fire triangle represents oxygen. Air contains about 21% oxygen; most fires require air with at least 16% oxygen content to burn under most conditions. Oxygen supports the chemical processes that occur during a wildland fire. When fuel burns, it reacts with oxygen from the surrounding air, releasing heat and generating combustion products, e.g., gases, smoke, particles. The process is known as oxidation.

Helping the audience(s) understand the fire triangle concept is critical to helping them understand why certain actions are taken, e.g., backfires, prescribed burns. Without this understanding, especially in a suppression situation, firefighters' actions may be misunderstood.

Fire Behavior

All wildland fires begin with an ignition source. Lightning is a common ignition source of wildland fires, reportedly causing nearly 80 percent of the remote wildland fires in the United States. Nine out of ten fires, however, are started directly or indirectly by people, through discarded smoking products, sparks from equipment in operation, arced powerlines, campfires, arson, and other means.

Fire behavior describes the manner in which fuels ignite, flames develop, and fire spreads. The fundamental influences on the spread of wildland fire include fuel type and characteristics, weather conditions in the area, and terrain.

Fuel

Because of the complicated combustion process that occurs during the ignition and spread of a wildland fire, it may be useful to describe for your audience the difference between fire and flame. Fire is a chemical reaction, and flame is the visible indication of that chemical reaction. When a flame is visible, the combustion is termed "flaming combustion." With "glowing combustion" one will only see embers.

Fuels char at relatively low temperatures, but once charred can continue to burn by glowing combustion. As fire spreads, there is constant ignition of new fuels through one of the three heat transfer mechanisms described earlier, and the fire continues to advance.

Weather

Wildland fires are affected by wind, temperature, and humidity in the burn zone. Strong winds can affect fire behavior by pushing the flames toward new fuel sources. Wind is able to pick up and transfer burning embers, sparks, and other materials that are capable of starting "spot fires." Blowing wind can also serve as a fuel drying source in moist areas. Wildland fires are capable of generating their own wind. Air above the hot flames becomes heated, causing it to rise. This movement allows fresh air to fill the vacuum provided; this fresh air supplies the fire with a fresh supply of oxygen. In essence fires can generate their own winds, fanning their own flames.

During the day, sunlight heats the ground and the warm air rises, allowing air currents to travel up sloped landscapes. At nightfall, the process is reversed. The ground cools and the air currents now travel down the slopes. Often fires will burn upslope during the day and downslope at night.

Temperature acts upon the spread of wildland fires because the temperature of the fuel affects how quickly or slowly they will reach their ignition point and burn. Because fuels are also heated by solar radiation, fires in the shade will not burn as quickly as those in the direct path of sunlight.

Humidity is a measure of the amount of moisture in the air. This moisture dampens the fuel, slowing the spread of flames. Because humidity is greater at night, fires will often burn less intensely at that time under normal circumstances, and therefore will not travel a great distance.

The combination of wind, temperature, and humidity affects how fast wildland fires can spread. These combinations will change throughout the day and night, and the presence of fire will impact each factor, causing even greater variation.

Terrain

Topography of a landscape also affects the spread of wildland fire. Every wildland fire is different in the way that it behaves because of the changing combinations of so many factors, but terrain remains constant and therefore allows for more constant predictions of how fire will behave in a specific area.

An explanation of terrain includes the shape of the landscape, its elevation, the slope direction and its exposure to sunlight, and the slope steepness. The shape of the land determines how much sunlight or shade an area contains, affecting temperature and wind conditions. Certain fuels grow better under different conditions, and the amount of shade or sunlight, the temperature of an area, and moisture received by an area all determine the type of fuel available for wildland fires. In addition, if the landscape has barriers, including highways, boulders and rock slides, or bodies of water, the fire will not spread as quickly.

Elevation and slope direction affect the type and temperature of the fuel to the degree in which there are shaded and sunny areas. Elevation also impacts how much wind and moisture the area receives. Slope steepness is important in that it contributes to how quickly the fire will reach the crest of the land form. When a fire begins at the bottom of a slope, the fuels located uphill are preheated by the rising air, helping them to easily catch fire when they come in contact with flames. Fires that begin uphill may deposit burning material that rolls downward, allowing more fires to begin downhill.

The Complexity of the Message

While helping an audience understand the basic aforementioned concepts, it is critical to convey the complexity. The biogeophysical science behind wildland fire requires multidisciplinary knowledge of chemistry, physics, geology, meteorology, and ecology. That knowledge is then interpreted to help predict and explain fire behavior. Each situation is different in that fire does not function within the framework of a static model.

Wildland fire, as it moves, involves a changing situation. Fire itself changes its own environment, e.g., winds. In essence, in managing a fire the professionals are mixing a recipe in which the ingredients are known but the quantities going in and out of the recipe are constantly changing as is the heat. Such analogies may help your audience better understand why wildland fire management is a demanding art and a science.

Refer to the *Wildfire—Feel the Heat Study Guide* (Mullins, 1999) in this *Communicator's Guide* for further discussion of the science of wildland fires. For those requiring an in-depth scientific explanation of wildland fire see Pyne, Andrews, and Laven (1996).

References

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Author: Elizabeth Hall

Condition Class Attributes: Defining Fire Regimes

Condition class attributes is an approach to defining and interpreting the importance of fire frequency in ecosystems. This concept is useful in helping wildland fire communicators convey to their audiences the science and management behind wildland fire.

Current "condition class" is defined in terms of departure from the historic fire regime, as determined by the number of missed fire return intervals with respect to (1) the historic fire return interval, and (2) the current structure and composition of the system resulting from alterations to the disturbance regime. Five combinations of fire frequency are defined. Groups I and II include fire return intervals in the 0–35 year range. Group I includes ponderosa pine, other long-needle pine species, and dry-site Douglas fir. Group II includes the drier grassland types, tall grass prairie, and some chaparral ecosystems. Groups III and IV include fire return intervals in the 35–100+ year range; and Group V is the long-interval (infrequent), stand replacement fire regime.

Three "Condition Classes" have been developed to categorize the current condition with respect to each of the five historic Fire Regime Groups. The relative risk of fire-caused losses of key components that define the system increases for each respective higher numbered condition class, with little or no risk at the Class 1 level. Features of each condition class are defined through a qualitative description of the current state of five key ecosystem attributes: (1) disturbance regime; (2) effects of disturbance agents; (3) potential production of smoke emissions; (4) hydrologic function; and (5) vegetative composition, structure, and resilience.

These first two fire regime groups occupy nearly all the lower elevation zones across the United States. They have been most affected by the presence of human intervention and analysis shows that these types demonstrate the most significant departure from historical levels. The departures are affected largely by housing development, agriculture, grazing, and logging. These areas are at greatest risk to loss of highly valued resources, commodity interests, and human health and safety. It is expected that these areas will receive primary focus of wildland management agencies in the future.

The Five Historic Natural Fire Regime Groups

Fire Regime Group	Frequency (Fire Return Interval)	Severity
I	0–35 years	low severity
II	0–35 years	stand replacement severity
III	35–100+ years	mixed severity
IV	35–100+ years	stand replacement severity
V	>200 years	stand replacement severity

Condition Class 1 (Groups I and II)

Disturbance Regime

The historic disturbance regime is largely intact and functioning as defined by the historic natural fire regime.

Disturbance Agents

The effects of insects and disease as well as the potential intensity and severity of fire are within historic ranges, but are increasing with length of current fire return interval.

Smoke Production

Smoke production is relatively frequent, but is low in volume and short in duration.

Hydrologic Function

The hydrologic functions are within normal historic range.

Composition, Structure, and Resilience

Vegetative composition and structure are resilient to disturbances from wind, insects, disease, or fire and Do not predispose the stand or its key components to a high risk of loss.

Condition Class 2 (Groups I and II)

Disturbance Regime

Moderate alterations to the historic disturbance are clearly evident, such as one or more missed fire return intervals.

Disturbance Agents

The effects of insects and disease as well as the potential intensity and severity of fire pose an increased threat to key components that define the system.

Smoke Production

Smoke production has increased both in volume and in duration and has increased potential to affect health and visibility values.

Hydrologic Function

Riparian areas and their associated hydrologic functions show measurable signs of adverse departure from historic conditions.

Composition, Structure, and Resilience

Both the composition and structure of vegetation has shifted towards conditions that are less resilient and are therefore more at risk to loss from wind, insects, disease, or fire.

Condition Class 3 (Groups I and II)

Disturbance Regime

The disturbance regime has been significantly altered and historic disturbance processes and effects may be precluded.

Disturbance Agents

The effects of insects, disease, or fire may cause significant or complete loss of one or more defining ecosystem components.

Smoke Production

Episodic smoke production is unpredictable and of high volume and long duration, posing significant impacts to human health, safety, and societal values.

Hydrologic Function

Hydrologic functions may be adversely altered, with significant increases in sedimentation potential and measurable reductions in streamflows.

Composition, Structure, and Resilience

The highly altered composition and structure of the vegetation predisposes the stand or ecosystem to disturbance events well outside the range of historic variability, potentially producing changed environments never before measured. Additional information can be found on these condition classes in *Protecting People and Sustaining Resources in Fire-Adapted Ecosystems—A Cohesive Strategy* published by the National Wildfire Coordinating Group.

Hardy and other researchers from the USDA Forest Service have provided the research to develop these condition class attributes. This group of researchers has developed a spatial database of historic natural fire regimes for the eleven western states to provide information to support prescription burning. The base-layer spatial data they used was a 159-class Land Cover Classification database derived from seasonal profiles from the USGS EROS Data Center. In order to assign fire regimes to Land Cover Characterization databases they added in biophysical data, Kuchler's unit data (4th code), and the ecological subregions based on Bailey's sections. The resulting knowledge will help decisionmakers determine what level of fire activity may be required. For example, can initial entry fire be used for maintenance? Can fire be used to achieve restoration objectives? Is supplemental mechanical treatment required as a precursor to prescribed fire?

While this level of scientific specificity may be more than many audiences need, communicators must fully brief themselves on emerging scientific thinking in order to more fully explain the science and management of wildland fire.

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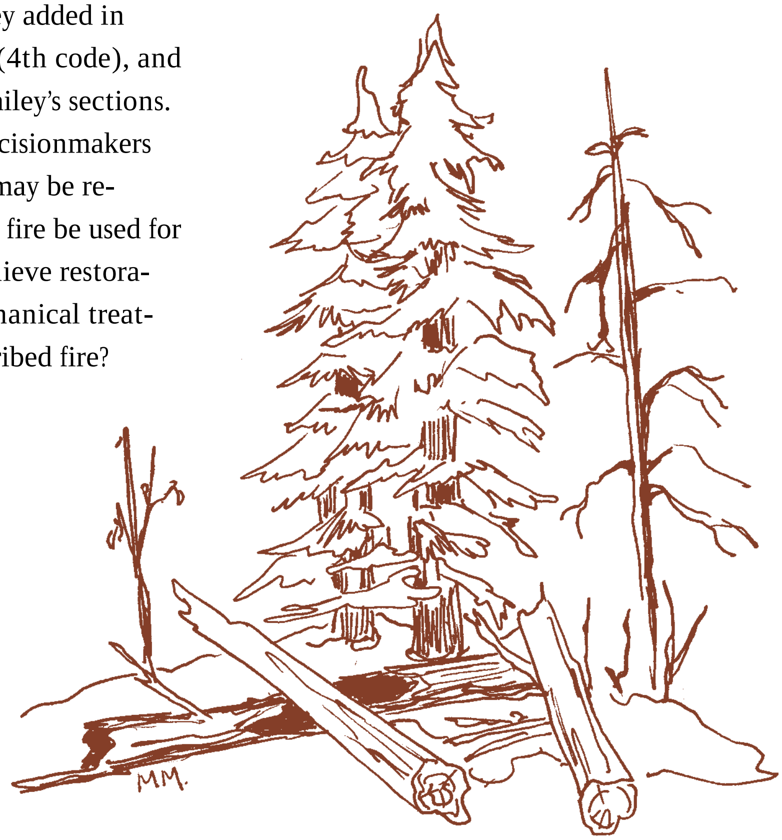


Fire Dependent Ecosystems of the United States

A central tenet for communicators is "relate to your audience." Historically, most terrestrial ecosystems in the United States were dependent to some extent upon fire. Addressing wildland fire using local examples has the potential to better help people relate. Seven major ecosystems are used as examples of how to concisely frame local descriptions.

Ecosystems, or ecological regions, are large geographic areas containing similar biological communities and abiotic conditions, such as temperature, rainfall, and seasons. They are tied through flows of energy. These ecosystems are often identified by the dominant plant communities found in the region. The plant species found in these biological regions are a function of many factors, including climate, interactions among species, and disturbance regimes such as fire. Fire occurs in nearly all terrestrial ecosystems, however, in some ecosystems wildland fire is one of the major factors in determining community structure and composition.

Fire disturbance regimes can be characterized by:

- effects of disturbance agents;
- potential production of smoke emissions;
- hydrologic functioning;
- vegetative composition, structure, and resilience.

See "Condition Class Attributes: Defining Fire Regimes" on page 11 for a discussion of the five fire regime groups.

The community structure and species composition at any given site are responses to various aspects of disturbance. Over time, disturbance regimes such as flood, drought, and fire have molded the composition, structure, and ecological processes of the world's ecosystems.

Organisms within these ecosystems have evolved to survive the disturbance regimes unique to an area. Species adaptations to disturbances can be thought of as the evolution of morphological and behavioral traits which allow for reproduction and the continuance of a species. Many plant species have important adaptations that allow them to survive, thrive, and even require fire for survival. However, it is important to recognize that not all adaptations that protect plants are a response to fire, but may be a response to other selective pressures, such as grazing or drought.

Many plants have evolved adaptations that protect them as a species from being extirpated by wildland fire, i.e., fire resistant adaptations. The most common example of fire protection is the thick bark on some species of trees in fire dominated ecosystems, such as ponderosa pine and bur oak. In addition, some species have protective coverings over critical plant parts; examples of these coverings are the needle and scale coverings over the buds on longleaf pine, and the below-ground meristem tissue (where growth occurs) in grasses.

Several adaptations relate plant growth to fire, i.e., growth-related adaptations. Some trees, such as ponderosa pine, actually increase their growth rate in the years following a fire; this response is visible in the annual rings in the cross section of trunks. Other growth-related adaptations include dormant buds that begin growing after limbs and branches are burned away, stimulation of suckering from the stumps of burned trees, and lignotubers (dormant below-ground buds in some legumes).

Several reproductive-oriented adaptations allow plants to take advantage of, or even require, wildland fire. Fire has been shown to trigger and/or increase seed release in some species, such as lodgepole and jack pines, and to stimulate flowering and fruiting in some shrubs and herbs. Some seeds remain dormant until the seedcoat is scarified, or cracked, which can result from intense heat or fire. Some pines have serotinous cones, in which the seeds are sealed in the cone by a waxy pitch that requires fire to remove the seals and free the seeds for germination.

Fire can also prepare seedbeds for germination by burning leaf litter. Some seeds require mineral soil for germination, and fire can release nutrients in the soil and make them available for sprouting plants. Likewise, fire can remove overstory plant material permitting sunlight to bathe the lower plant strata.

These adaptations, in combination with the local fire regime at a specific site, play an important role in determining the composition of the plant community. The immediate impact of wildland fire on animals is generally less intense, as both vertebrates and invertebrates have been shown to be fairly successful at avoiding being burned in fire. However, major changes in the plant communities following a fire have significant impacts on the animal communities that inhabit these ecosystems.

Over time, however, the impacts of human generated fire can have major consequences for animals. For example, the movement of American bison to the eastern United States in the 1500s may have resulted from Native Americans burning in the east which opened more grazing for bison. Recent studies of ancient Aboriginal “fire-stick farming” practices in Australia beginning 50,000 years ago suggest fire impacts as the reason for extinction of certain large animals.

It is essential for communicators of wildland fire information to stress the importance of fire on the ecosystem health, and to inform audiences that wildland fire management practices used in one ecosystem will not necessarily benefit another. This section of the *Guide* provides a brief overview of seven fire-dependent ecosystems within the United States to illustrate how to frame stories when communicating with audiences about the role of fire.

Midwest Tallgrass Prairie

Historically, tallgrass prairies covered parts of Nebraska, Illinois, Iowa, and Kansas. To the west, the tallgrass prairie graded into shortgrass prairie. To the east the tallgrass prairie included increasing numbers of trees, first as scattered oak savannahs and gallery forests, eventually becoming forests with prairie openings. These extended eastward into the Ohio Valley.

Tallgrass prairie is primarily made up of grasses and forbs, with some shrubs and trees. Prairie plant communities are a result of fire and drought, although some community structure is in part from grazing by bison and elk. Drought acts both as a direct stress on the prairie ecosystem, and to make conditions more likely that fire will occur by drying potential fuels. In pre-Colombian times, natural fire sources were primarily from lightning strikes, although there is evidence that deliberate fires started by Native Americans were also common. Fires in the prairie usually occurred in five- to ten-year cycles, with moderate regularity. Fire in tallgrass prairies acts to burn above-ground biomass, killing woody plants, allowing sunlight to reach the soil, and changing the soil pH and nutrient availability. Grassland fires can cover large areas in a short time as fire fronts are driven by prairie winds. However, because grass provides a low quality of fuel, grassland fires usually are not intense.

Productivity usually increases following a fire in the prairie. Growth is stimulated by the removal of litter and preparation of the seedbed. In addition, perennials have greater seed production, germination, and establishment after a fire. The seeds of some forbs, such as prairie sunflower, scarify and leave dormancy following fire. Growth of native species such as big bluestem, little bluestem, and Indian grass all increase significantly following a fire. Fire promotes grasses at the expense of woody species; those woody species that do occur in savannahs are usually thick-barked species such as bur oak. Because of predominantly westerly winds across American prairies, trees are sometimes found on the eastern bank of streams and rivers that stop fires spread by these winds.

When fire is removed from a prairie ecosystem, woody shrubs and trees eventually replace grasses and forbs. Mowing is not a good replacement for fire in prairies because it does not reduce litter. Grazing is not a good replacement because it exerts a selective pressure on some grass species while leaving others untouched.

Almost exclusively, burning is prescribed for the restoration and maintenance of prairie reserves. In most managed prairies, prescribed fire is introduced on a two- to three-year cycle. The time of the year during which these fires are ignited is of primary importance. Plant recovery following a prairie fire is fastest in the spring and fall when soil moisture is high and plants are not producing seeds. If the area is burned when soil moisture is low, or when plants are starting to produce seeds, the recovery will take longer following the fire.

Southwestern California Chaparral

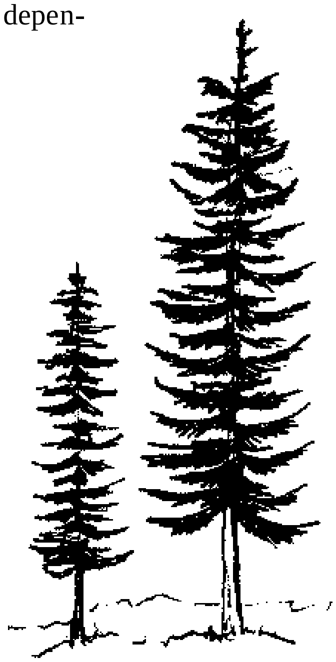
Chaparral is a general term that applies to various types of brushland found in Southern California, Arizona, New Mexico, and parts of the Rocky Mountains. True chaparral exists primarily in Southern California and describes areas that have a Mediterranean-like climate with hot, dry summers and mild, wet winters. The chaparral in this region is primarily fire-induced, and grows in soils that are shallow and unable to hold water. Generally, the terrain is steep and displays severe erosion. Variations in species cover throughout the area is attributed to the soil type and exposure, the altitude at which it grows, and the frequency of wildland fires.

Chamise (greasewood) is a common plant in this ecosystem; other important shrubs include manzanitas, *Ceanothus*, and scrub oaks. Natural fires occur in 15- to 25-year cycles, with high regularity. Plant growth in southern California chaparral occurs during the wet winter months; this vegetation dries during the dry summer months when winds blow from the inland deserts toward the Pacific Ocean. Fires usually occur during the late summer Santa Ana winds, which are strong (up to 60 mph) and dry. These winds tend to drive fire rapidly through the dry brush.

Plants in this ecosystem are adapted to the Mediterranean climate, local soils, and the fire regime. Fire adaptations include vigorous stump sprouting after fires by many shrubs, including the manzanitas, *Ceanothus*, and scrub oak. Chamise produces dormant seeds that require fire for scarification; these seeds create a large seed bank during non-fire years. In addition, most chaparral plants seed quickly, usually within three to five years after sprouting. Many of the shrubs, especially chamise, promote fire by producing highly flammable dead branches after about 20 years. Another chaparral plant, *Ceanothus*, has leaves that are coated with flammable resins. Fires occurring at intervals greater than 20 years are often high intensity because of the large amount of fuel existing in shrub tops. Many nutrients are locked in the foliage of chaparral plants. Through burning, these nutrients are recycled back into the soil.

After fires in chaparral, forbs are usually profuse on the newly opened floor. After a year, the plant community is dominated by annual grasses. Five years after a fire, chaparral shrubs once again dominate the ecosystem; for this reason, more frequent fires favor grasses over shrubs. Fire has not been successfully removed from this ecosystem, so how the community would respond to lack of fire is not well-known, although non-fire adapted trees and shrubs might replace the chamise, manzanita, and *Ceanothus*.

Wildland fire control in the southern California chaparral ecosystem is very difficult because of the existence of Santa Ana winds, the length of the summer season, and the heat and dryness present throughout the season. This ecosystem contains water-repellent soils, loose surface debris, and steep terrain, all adding to the high risk of unwanted wildland fire. Obstacles to using prescribed burning include the nearness of housing (urban-wildland interface) and the issue of smoke management. Burning also increases the amount of soil erosion, which is especially problematic in developed areas. Some work has been accomplished to replace the chaparral plant community with grasses, but this practice further threatens the existence of the species dependent on this ecosystem.



Ponderosa Pine in the Southwest and Intermountain West

Ponderosa pine ecosystems occur as transitions between grasslands and deserts at lower elevations and higher level alpine communities. These ecosystems are found from the southwestern mountains as far north as Washington and Oregon, and east to the Dakotas, sometimes as nearly pure stands of ponderosa pine, and sometimes mixed with other species, such as Douglas fir. This forest community generally exists in areas with annual rainfall of 25 inches or less.

The characteristic surface cover in a ponderosa pine forest is a mix of grass, forbs, and shrubs. The natural fire regime has a cycle of five to 25 years, with moderate regularity. These fires tend to be low intensity ground fires that remove woody shrubs and favor grasses, creating open, park-like ponderosa stands.

The life history of ponderosa pine is well-adapted to high frequency, low intensity fires. These fires burn litter and release soil nutrients, thus providing a good seedbed for ponderosa pine seeds. For the first five years of their life cycle, ponderosa pine seedlings vigorously compete with grasses for survival and are vulnerable to fire. Eventually, at about five or six years of age, the tree begins to develop thick bark and deep roots, and shed lower limbs. These factors increase its ability to withstand fire and decrease the possibility of a fire climbing to the crown; crown fires can kill ponderosa pines. Ponderosa needles on the ground facilitate the spread of low intensity ground fires, and reduce grasses that can intensify groundfires.

In ponderosa pine stands, fire is generally prescribed on five- to ten-year intervals to reduce fuel loads. Shorter burn intervals have insufficient fuel built up to maintain the fire, and longer periods may run the risk of causing tree-killing crown fires. Prescribed fires usually result in maintenance of stand composition.

Douglas fir is commonly found in association with ponderosa pine, but is able to survive without fire. Additionally, Douglas firs possess characteristics that enable them to withstand fire when it does occur. For example, this species is more resistant to fire than most other conifers. Additionally, the Douglas firs' abundantly produced seeds are lightweight and winged, allowing the wind to carry them to new locations where seedlings can be established. Douglas fir regenerates readily on sites that are prepared by fire. In fact, nearly all the natural stands of Douglas fir in the United States originated following fire. One of the main benefits of fire in these forest communities is the removal of fuel and consequent reduction of the chance of severe crown fires. Because Douglas fir exists in the presence of other types of trees, the life cycles of many species must be considered when timing a prescribed fire in this type of forest community.

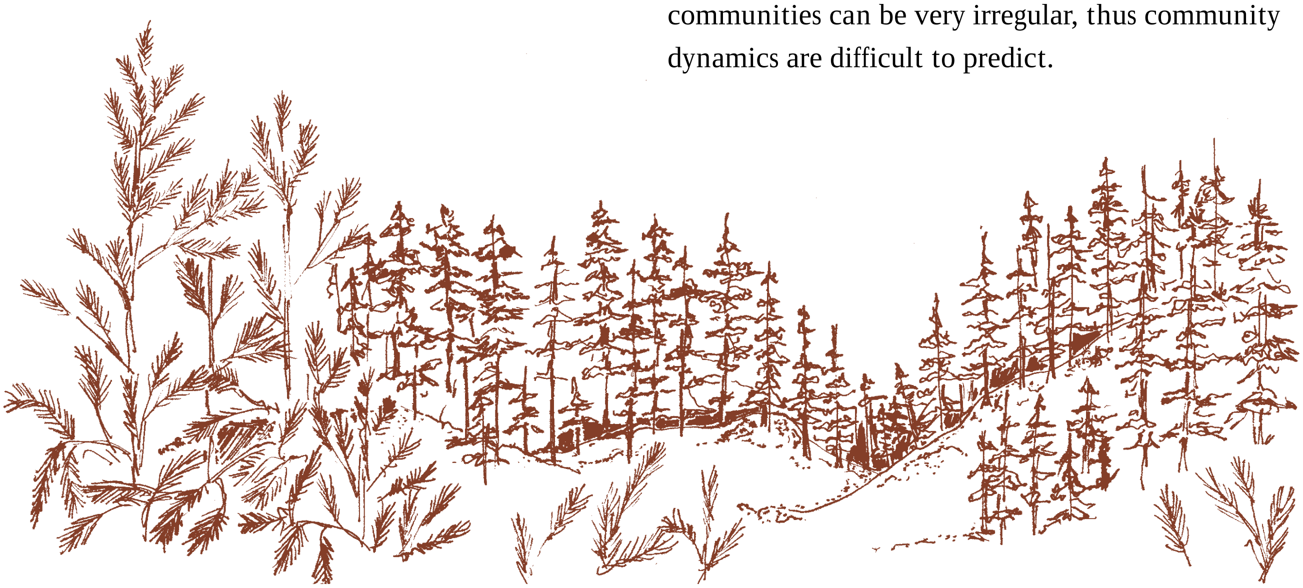
Lodgepole Pine Communities of the Rocky Mountains

Lodgepole pines are found throughout the Rocky Mountains of the western United States, generally in unmixed stands at higher elevations. Major fires occur at intervals of 200 to 300 years in this ecosystem, and these fire events are often high intensity crown fires that kill trees. Each successional stage of a lodgepole pine community displays different reactions to fire.

At 40 to 50 years following a stand-replacing fire, herbaceous plants and lodgepole seedlings grow between the snags and the logs that were damaged by the fire. The forest tends to resist fire at this stage, in that the only fuel available are large logs that do not readily burn. From the age of 50 to 150 years, seedlings grow to a height of 50 feet, and the stands become so dense that little sunlight reaches the forest floor, therefore suppressing the growth of the understory. The sparseness of undergrowth also discourages the possibility of wildfire.

It is during the next successional stage of 150 to 300 years that the threat of wildland fire increases. Because of overcrowding, some of the lodgepole pines begin to die, which allows sunlight through, spurring vegetative growth. After 300 years, the original lodgepole pines die, making the forest highly susceptible to wildland fire. For example, the lodgepole pine stands in the Yellowstone area during the 1988 fires were 250–350 years old.

When fire does not occur, lodgepole pines are sometimes gradually replaced by Engleman spruce and subalpine fir, although the successional pathway is site dependent. Fire regimes in lodgepole pine communities can be very irregular, thus community dynamics are difficult to predict.

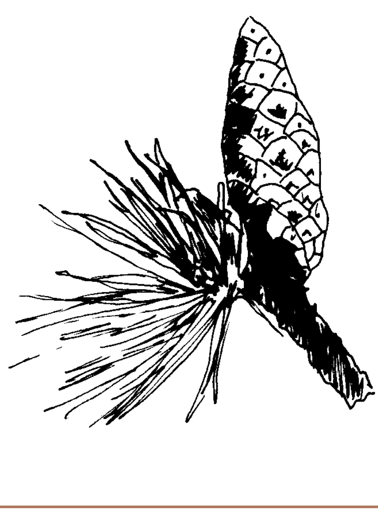


Wildland fire management in lodgepole pine communities can be problematic. Because there tend to be high intensity crown fires, allowing lightning ignited fires to burn, the results can be in vast acreages being burned, and fires which are difficult to contain within management units. Prescribed fire is difficult to manage for the same reasons, and can endanger nearby human communities. Fire suppression, however, creates a fuel buildup that is difficult to manage, and suppression is not consistent with maintaining ecological communities.

Southern Pine Communities

Southern pine forests, consisting mainly of loblolly, shortleaf, or longleaf pines are found from Texas east to Florida, and north to Maryland. Various species of oaks are often present, especially when fire has not occurred recently. Shrubs can also be present, such as saw palmetto and bayberry; grasses are also common, such as little bluestem and wiregrass.

Lightning ignited fires in southern pine communities are common. More frequent fires favor longleaf pines, which are more fire adapted; less frequent fires tend to favor shortleaf and loblolly pines. Frequent fires also create pine savannahs when understory shrubs are burned away, favoring the establishment of grasses beneath the pines. In cases where fire does not occur for 25 years or more, such as when fire is removed from the system or on wet sites where fire seldom occurs, hardwoods such as oaks and hickories gradually replace the pines.



Like many fire-adapted trees, longleaf pine requires mineral soil for seed germination, and thus ground fires prepare the seedbed by removing litter and releasing soil nutrients. The longleaf seedling grows slowly in the early years, devoting much energy to developing a thick root that is protected from fire, and to a dense protective layer of needles around the buds. Loblolly and shortleaf pines are less fire tolerant than longleaf pine, but the thick barks of these species also make them more fire tolerant than most other competitive tree species.

Jack Pine Communities of the Great Lakes Region

A mixture of pines and other tree species is found in the forests of the Great Lake states. Red, white, and jack pine grow among paper birch and aspen. Grasses, forbs, and shrubs such as big bluestem, little bluestem, raspberry, blueberry, and huckleberry grow under the trees of these communities. The communities of the Great Lakes states have suffered many disturbances since European settlement, making it difficult to determine the "natural" state of these ecosystems.

Jack pines are small trees, rarely exceeding 80 feet (about 24 meters) in height. They occur in poor soils, usually in open "pine barrens," and often form savannahs when grasses are present on the thin soils. Fires occur in jack pine stands approximately every 125 to 180 years.

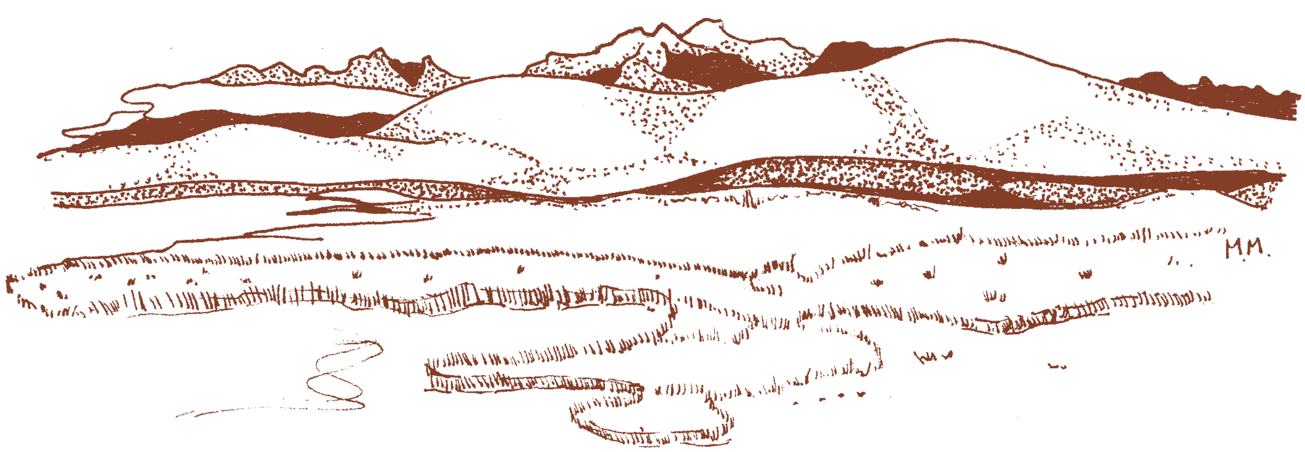
Jack pine is well-adapted to fire. Serotinous cones, which have a waxy outer coating to protect the seeds, remain on the tree rather than dropping to the forest floor. Seeds can remain viable on the tree for 20 years or longer. When a fire occurs, the thick cone protects the jack pine seed from the intense heat. Jack pine seeds have been known to still be viable after exposure to heat at 1000 degrees Fahrenheit. That heat, however, opens the scales of the cone and releases the seed onto the ground where the fire has removed much of the existing vegetation and litter. Jack pine seeds require contact with mineral soil to germinate, so fire serves to prepare the seedbed, reduce competition from other plants, and release the jack pine seed. In addition, the short stature of jack pines makes crown fires a high likelihood; these very crown fires are necessary to release the seeds from dormancy.

When fire is withheld from jack pine stands, they are replaced by other boreal tree species, such as balsam fir, white spruce, and the hardwoods that occur in this ecosystem. Prescribed fire is used in jack pine stands in central Michigan in order to maintain habitat for the rare Kirtland's warbler, which requires young jack pine stands for nesting.

Alaska's Boreal Forest and Tundra

Alaska is a vast landscape covered with boreal forest and tundra, all prone to wildland fire. The boreal forest is found in southern Alaska extending as far north as Fairbanks. Tundra is found in the higher elevation of this zone. Tundra extends from the Brooks Range north to the Arctic Ocean.

While the boreal forest has large vegetation (e.g., spruce and birch trees) and nutrient-ladened soil, the tundra is a low landscape comprised of scrubby and herbaceous vegetation, often only a few inches high. Much of the tundra soil and its nutrients are locked in permafrost. Often the soil is shallow; in some places it is no deeper than the shallow root structure of the tundra vegetation.



On the south-facing slopes of the boreal forest are spruce, birch, and aspen. North-facing slopes contain mostly black spruce and birch. Both of these slopes exhibit a unique succession; the successional stages are greatly impacted by wildland fire.

Following a fire, cottongrass, fireweed, and other herbaceous plants invade. Shrubs and berries move in after a few years only to be replaced by more mature trees such as willow, aspen, and birch. Eventually the spruce gets established and dominates, usually until the next fire. The heavy mass accumulation of litter makes these forests most susceptible to fire.

Fires in the boreal forest and tundra typically burn in a patchwork leaving a mosaic across the landscape. Time of year, moisture present, wind speed and direction at the time of the fire, and biomass accumulation since the last fire, etc., all add to the rendering of the mosaic.

Because of Alaska's cool year-round temperatures, vegetation decays at a very slow rate, thereby releasing nutrients at a very slow rate. Following a fire in the boreal forest or tundra, large amounts of nutrients are released. Plants exploit this opportunity, especially the early successional plants. In turn, wildlife exploit the lush growth. Consequently, Alaska's plant and animal communities are highly dependent on fire regimes.

Summary

Wildland fire occurs naturally and plays varying roles in nearly all terrestrial ecosystems. Because different types of ecosystems produce and accumulate fuel more quickly than others, the wildland fire frequency and intensity are determined by the type and the stage of development of the ecosystem in which it occurs. Depending on the fire regime, many species evolve adaptation to fire, making fire important for competition with other species, or even necessary for reproduction. Fire, in a natural or prescribed form, is important to the maintenance and health of most ecosystems.

References

Archibold, O.W. 1995. *Ecology of World Vegetation*. London; New York: Chapman & Hall.

Pyne, S.J., P.L. Andrews, and R.D. Laven. 1996. *Introduction to Wildland Fire*, 2nd Edition. New York: John Wiley & Sons, Inc.

Author: K. Jeffrey Danter

Fire Effects

While the fires blaze, the focus is on the scale of the fire … thousands of acres burned, where are the fire lines, what are the risks? After the fire, society tends to focus on "effects." What is the impact on soil and accelerated erosion scenarios as the rains return to the Los Alamos area after the fire of 2000? What will be the impact on streams and fish populations?

During the fires of 1988 in the Yellowstone region, much media attention was given to impacts on wildlife. How many bison died? How will the fire affect their winter range?

From the broad citizenry perspective, it is natural to relate the broader questions of impact or effect on water, plants, and animals—those more tangible elements of the ecosystems. To answer these questions though the wildland fire communicator needs an authoritative source to which to turn.

The National Wildlife Coordinating Group's (NWCG) publication *Fire Effects Guide* provides an in-depth review of the multiple effects of fire. This edited document provides a concise background on the ecological and physical science related to aspects of fire that can help guide message development.

The *Fire Effects Guide* is divided into twelve chapters:

- Development of Objectives
- Fire Behavior and Characteristics
- Fuels
- Air Quality
- Soils, Water and Watersheds
- Plants
- Terrestrial Wildlife and Habitat
- Cultural Resources
- Prefire and Postfire Grazing Management
- Evaluation
- Data Analysis
- Computer Software

These sections are supported by an extensive glossary and bibliography on fire effects. Understanding each of the twelve sections presented is critical to understanding and formulating a comprehensive and cohesive message for your audience or for others such as the media. These groups expect the communicator to translate the science behind the fire into language and concepts that relate to their realm of understanding.

For example, if you are interpreting the long term impacts of the Mesa Verde fire of the summer of 2000, all twelve sections presented are relevant to building a cohesive story. You cannot discuss cultural effects, such as the trade-offs between degradation of some structures and artifacts and the uncovering of others, unless you also discuss ecological effects.

To provide you with an overview of the *Fire Effects Guide* contents, the following chapter titles, their author(s), and edited summaries from the document are provided.

Chapter I—Development of Objectives

Author: Tom Zimmerman

Land management programs are objective driven. Objectives must be based on an amount of information sufficient to determine if a change from the present condition to the proposed condition can be achieved. Establishing objectives is a task of major importance and deserves an allotment of sufficient attention and time. Both objectives and fire effects information become more precise as site specificity increases.

Fire Effects Guide (NFES #2393) *is available from:*
National InterAgency Fire Center
Attn: Supply
3833 S. Development Ave.
Boise, ID 83705

http://www.nwcg.gov/pms/pubs/catalog.htm

Chapter II—Fire Behavior and Characteristics

Author: Melanie Miller

Knowledge of the behavior and characteristics of wildland fire is important both for managing fire and for understanding and interpreting the effects of fire. The heat regime created by a fire varies with the amount, arrangement, and moisture content of flammable materials on a site. Trained and experienced people can predict (within a factor of two) some aspects of the behavior and heat release of a flaming front of a fire, and some associated fire effects such as crown scorch. However, many fire effects are related to characteristics of fire that are not related to the behavior of the flaming front and cannot presently be forecast.

Chapter III—Fuels

Author: Melanie Miller

Fuels are an integral part of most wildlands. At some time after death, or while still alive, all vegetation becomes potential fuel. The single most important factor controlling the flammability and consumption of fuels is their moisture content. The moisture content of dead wildland fuels is regulated by environmental factors, while that of living plants is largely controlled by physiological processes. Other fuel properties can also affect the degree of consumption. All direct effects of fire result from the characteristics of the heat regime of the fire, which is controlled by the manner in which fuels burn. Management of fuels is important because by doing so, the heat regime of a fire is also regulated.

Chapter IV—Air Quality

Authors: Larry Mahaffey and Melanie Miller

The effects of smoke on health, air quality, and regional haze are very important to all land managers. They must recognize the need to manage smoke from wildland fires using the best available control measures. Every manager must determine the level of smoke management necessary to provide the least impact on the public, both in terms of health and visibility. The effects of smoke on firefighters also must be considered when managing wildland fires. If federal agencies do not take a rational, voluntary approach to smoke management, a mandatory approach may be provided that makes it more difficult to meet resource management goals and objectives.

Chapter V—Soils, Water and Watershed

Author: Bob Clark

The effects of fire on soils, water, and watersheds are extremely variable. In some cases, such as accelerated erosion, the outcome is reasonably predictable and mitigating measures such as rapid revegetation are necessary. In other cases, such as change in off-site water yield after burning, the outcome is much less predictable because it appears to depend on site-specific characteristics and on unpredictable climatic events. The application of mitigating measures must be based on local experience and local research. In almost all cases, the establishment of a local database would provide useful information for future events.

Chapter VI—Plants

Authors: Melanie Miller and Jean Findley

Plant response to fire is a result of the interaction of the behavior and characteristics of a fire with the characteristics of a plant. Plant community response is a product of the responses of all plants on a burned area. The response of an individual species of plant or plant community can vary among fires or within different areas of one fire. This is because of variation in fuels, fuel moisture conditions, topography, wind speed, and structure of the plant community itself, causing the heat regime of a fire to vary significantly in time and space. The immediate effects of fire can be modified by postfire weather and animal use.

Fire can cause dramatic and immediate changes in vegetation, eliminating some species or causing others to appear where they were not present before the fire. Monitoring techniques that are used to detect trends in vegetative communities are often not appropriate, either because they are not sensitive enough to detect the changes that have occurred, or they provide statistically inadequate samples. Fire effects on plants and plant response to fire treatments are predictable if the principles and processes governing plant response are understood. If burning conditions, fire treatment, and vegetation response are properly monitored, the fire effects that are observed can be interpreted, and our ability to predict fire effects on plants will increase.

Chapter VII—Terrestrial Wildlife and Habitat

Author: Loren Anderson

Fire is a shock—frequently, nearly instantaneous—to the ecological setting involved according to authors cited in this chapter. Some wildlife species are able to adapt to the rapid change in environment and some cannot. The habitat for some species is greatly improved, while for others it may be degraded if not eliminated, and there will be endless variation in between. No fire—either wild or prescribed—is uniformly "good" or "bad." Effects are differentially imposed.

Fire effects on wildlife and wildlife habitat revolve around successional theory. Habitat structure tends to follow successional trends in most plant communities. Fire event intervals play a significant role in these trends.

Faunal succession tends to follow floral succession but they do not uniformly correlate. To understand effect, a series of questions must be asked.

Addressing the overall effect of fire on wildlife for a given area that has burned is most easily approached by going from the general to the specific, e.g., as illustrated by the following questions:

- What was the original successional stage and structural condition?
- What life forms or guilds were associated with those preburn conditions?
- What will the new successional stage and structural makeup be?
- What life forms or guilds will be favored by the new conditions?
- How were species of management or public interest affected?
- How may any obligate or otherwise sensitive species have been affected?

A righteous attempt at providing for desired fire effects through prescribed burning or evaluating wildland fire effects on wildlife and its habitat requires an integrated effort of disciplines. An appreciation of the historical perspective can be invaluable. Contributions by plant and fire ecologists are essential. Postburn management is absolutely critical. Obtaining good management necessarily requires close coordination with and commitment from specialists in range, forestry, recreation, and others. Without adequate monitoring and evaluation, little knowledge can be gained, and even less shared.

Chapter VIII—Cultural Resources

Author: Richard C. Hanes

Damage to cultural resources posed by wildfires and prescribed fires can be severe, ranging from chemical alteration of cultural materials to exfoliation of building materials and rock art panels. However, almost all impacts can be avoided through advanced planning. Protective measures can include removal of high fuel loads by hand or prescribed fire, careful use of fire breaks for avoiding fire effects on wooden structures and other highly susceptible resource values, and use of archaeological monitors on wildfires in sensitive areas to avoid fire suppression damage.

The experiments and observations thus far conducted indicate that cultural materials below the surface, unless directly exposed to a burning duff layer or burning underground roots, normally do not sustain significant damage, if any at all according to research cited in this chapter. Ground surface temperatures have been documented in excess of 800˚ F (427˚C), but only 100˚F (38˚C) at 2 inches (5 centimeters) below the surface. Obviously, the magnitude of fire effects on the soil and its contents is proportional to heat penetration. In conifer forests, for example, temperatures of 200˚F (93˚C) have
been recorded 0.5 inch (1.3 centimeters) deep in the soil, with duff layers considerably above that figure. Obviously, such heating depends on the thickness of the duff layer, duff moisture content, amount and moisture content of large diameter dead woody fuels, and soil type and its moisture content. Given current knowledge of fire effects on cultural resources, it is apparent that fires involving larger fuel loads, longer duration burns, and large total heat release pose significantly greater hazards to cultural resources than fires with short duration "cool" combustion temperatures.

Chapter IX—Prefire and Postfire Grazing Management

Author: Ken Stinson

Proper site management based on specific objectives and plant species is essential in the management of fire effects. Improper grazing management can easily nullify efforts put into prescription burning or wildland fire rehabilitation, as well as impede natural vegetative recovery after a fire. Impacts of long-term grazing management before and after a fire can be easily overlooked; therefore, proper grazing management including the appropriate kind of livestock,
the stocking rate, the season and the intensity of utilization, and the length and frequency of use are most important.

The period of nonuse by livestock necessary after a fire varies considerably with the vegetative composition, site conditions, resource conflicts, and objectives of the burn. Grazing closures apply to all fire sites, whether they are artificially reseeded or recovery is by natural means. In some situations, the only way to ensure nonuse of critical areas after a fire is to construct fences.

Proper grazing management before and after a fire has a major impact on fire effects, vegetation changes, economics, and rehabilitation success.
In analyzing fire effects, several site selection criteria should be considered, including the site potential, the ecological condition, the presence of desirable and invader plant species, the acreage of burn within the management unit, and the livestock management. The consideration and implementation of these factors determines the benefit/cost ratio and the success of a burn project or postfire rehabilitation effort.

Chapter X—Evaluation

Authors: Ken Stinson and Melanie Miller

Evaluation of both monitoring data and the impacts of postfire activities must be conducted in order to ensure that lands receive the best possible fire treatment, rehabilitation, and postfire management. Once we have monitored and evaluated enough projects and management actions on similar sites, and adjusted our actions based on these results, we can become more confident that the proper treatment is being implemented. The same degree of monitoring and evaluation need not be carried out on all subsequently treated areas if vegetation type, soil type, and treatment prescription are similar to that of other successful treatments. However, it is professionally unacceptable to conduct no prefire or postfire monitoring or site observation, to assume that an area is ready for grazing because the designated length of time has passed since the occurrence of fire, or to conduct no evaluation of the implementation or effectiveness of postfire site management in preserving or enhancing site quality. Without some check on the results of our activities, accumulated assumptions can lead to land treatments that do not meet resource management goals and objectives, and lead to deterioration, instead of enhancement, of site quality.

Chapter XI—Data Analysis

Author: Robert Clark

Statistical analysis of data and interpretation of results are helpful for understanding fire effects and provide an essential tool for the decision-making process. Calculation of the appropriate sample size is essential, and is based on desired precision and confidence levels. The t-test for paired plots and chi-square analysis of counts, are particularly useful for understanding fire effects. Other, more sophisticated techniques may require the assistance of a statistician.

Chapter XII—Computer Software

Author: Melanie Miller

Computer technology and applications are developing so quickly that any list of software is incomplete as soon as it is published. Specialized computer programs, called expert systems, may be available in the next few years. Expert systems are being developed or planned that can assist in the development of fire prescriptions to meet specific resource objectives, and to achieve specific fire effects. Agency fire management and air quality specialists can be contacted for information about future computer software development.

Collectively, this and similar documents and a plethora of information now appearing on the World Wide Web, provide the wildland fire communicator with the scientific basis necessary to formulate messages that reflect the best science and management to date.